



New species of *Hypasmocoma* (Lepidoptera, Cosmopterigidae) from the remote Northwestern Hawaiian Islands of Laysan, Necker, and Nihoa

PATRICK SCHMITZ¹ & DANIEL RUBINOFF^{2,3}

Department of Plant and Environmental Protection Sciences, 310 Gilmore Hall, University of Hawaii, 3050 Maile Way, Honolulu, Hawaii, 96822 USA.

E-mail: ¹pschmitz@hawaii.edu; ²rubinoff@hawaii.edu

³ Corresponding author

Abstract

The endemic Hawaiian cosmopterigid moth genus *Hypasmocoma* Butler, 1881 contains 315 described species, making it one of the Archipelago's most diverse radiations. However, only one species was previously described as endemic to the Northwestern Hawaiian Islands (NWHI), and prior taxonomic work in the region has been problematic. The NWHI represent a series of much older island remnants and atolls that were formerly high islands of much greater diversity. Systematic relationships within and between *Hypasmocoma* on the Northwestern Hawaiian Islands may have implications for understanding not only the biogeography of *Hypasmocoma* but of Hawaiian radiations in general. We describe eight new species of *Hypasmocoma* endemic to the NWHI: *H. laysanensis* **sp. nov.** and *H. ekemamao* **sp. nov.** from Laysan Island, *H. opuumaloo* **sp. nov.** and *H. mokumana* **sp. nov.** from Necker Island, and *H. nihoa* **sp. nov.**, *H. kikokolu* **sp. nov.**, *H. menehune* **sp. nov.**, and *H. papahānau* **sp. nov.** from Nihoa Island. This work represents the first inclusive taxonomic treatment of *Hypasmocoma* in the NWHI and may serve as a basis for studies both of *Hypasmocoma*, and broader biogeographic research on the NWHI.

Key words: Microlepidoptera, new species, endemic, Northwestern Hawaiian Islands

Introduction

The endemic cosmopterigid moth genus *Hypasmocoma* Butler, 1881 is an example of one of the greatest radiations in the Hawaiian Islands. A remarkable trait of some species of *Hypasmocoma* is the spectacular diversity of cases the larvae carry through development as shelters (Zimmerman 1978). Although 315 species of *Hypasmocoma* have been described, all but one are from the large, relatively young, main Hawaiian Islands (0.5-5 million years old). Only *H. neckerensis* (Swezey 1926) was described from the remote island fragments and atolls that make up the much older Leeward (7-21 million years old), or Northwestern Hawaiian Islands (NWHI), which were recently proclaimed the Papahānaumokuākea Marine National Monument. Until recently it was unclear if the lack of species from the NWHI was the result of an impoverished fauna that never fully colonized the ancient declining islands, or the result of inadequate sampling. NWHI *Hypasmocoma* specimens that had been identified by Swezey (1926) were erroneously thought to belong to species already described by Walsingham (1907) from specimens collected on the main islands (Zimmerman 1978). These misidentifications included three *Hypasmocoma* species identified by Swezey (1926) from Nihoa and Necker Islands and the unfortunate record of a species from Laysan Island based on a single larval case which had an emergence hole from a parasitoid (Fullaway 1914). In his preliminary fragmentary notes, Zimmerman (1978) mentions a total of possibly eight species collected on rocks or at lights and occurring on the NWHI, with several kinds of larval cases impossible to associate properly. The few samples that were available did not ameliorate the systematics of the group. We have begun a systematic and phylogenetic

analysis of the entire genus, including a significant rearing effort to establish relationships among larval case, larval ecology, habitat, and adult habitus for a wide variety of species (Schmitz & Rubinoff 2008).

The reconstruction of a NWHI *Hypasmocoma* phylogeny will be important in terms of understanding the fate of lineages on these subsiding and eroding islands. The NWHI bear special significance for Hawaiian biogeography because they may serve as repositories for species or lineages that colonized the archipelago more than 5 million years ago, before the oldest of the current high islands, Kauai, emerged. Because the summits of many of the NWHI once exceeded 1000 meters (Price & Clague 2002), they supported drastically different and far more diverse terrestrial biotas than are currently maintained. In fact, evidence from *Megalagrion* McLachlan, 1883 (Insecta: Odonata) (Jordan *et al.* 2003) and *Drosophila* Fallen, 1832 (Insecta: Diptera) (Bonacum *et al.* 2005) suggest that the ancestors of these groups colonized the region long before the current high islands arose. As such the systematics of *Hypasmocoma* in the NWHI has implications for Hawaiian biogeography in general, particularly since most current Hawaiian lineages are thought to be of recent (< 5 million years ago) origin (Price & Clague 2002). The following represents the description of eight new species from the remote NWHI found as part of this research effort.

Material and methods

The specimens forming the basis of this study were all reared from case-making larvae collected on the NWHI of Laysan, Necker, and Nihoa in 2004, 2007, and 2008. Although intensive fieldwork was conducted for one week in May 2007, no adults or larvae of *Hypasmocoma* were found on Midway Atoll. Cases of *Hypasmocoma* specimens collected in the field were put in Petri dishes and larvae were offered lichens, carrots, and commercial fish food (TetraMin®). For each collecting event, a unique data log entry (e.g., #DR07G8) was created: it includes date and location of capture, digital picture of larva in case, record of larval behavior, date of adult moth emergence, and digital picture of adult moth.

In listing the label data of the holotypes, the information is copied as found on the labels with slashes to express changes of lines and abbreviations spelled out in square brackets. For the lists of paratypes, the information is recorded without indications of line changes. The abbreviations are spelled out only once at first encounter. For each species' holotype, the data label is printed in black on white card stock while the holotype label is hand-written in black ink on red card stock. The following acronyms are used: BPBM for Bernice Pauahi Bishop Museum (Honolulu, USA), MHNG for Muséum d'histoire naturelle de Genève (Geneva, Switzerland), UHIM for University of Hawaii Insect Museum (Honolulu, USA), and USNM for National Museum of Natural History (Washington, D. C., USA).

Genitalia were dissected after the abdomen had macerated in a cold 20% KOH solution overnight. The dissected parts were kept in lactic acid stained with orange G to stain hard tissue for descriptive purposes. Genitalia were subsequently stained with chlorazol black to stain membranes, fixed in Ethyl alcohol and Isopropanol, and mounted on slides in Euparal. The forewing and case lengths were measured with a reticule on a stereomicroscope. The illustrations of the moths and genitalia were respectively made with a JVC KY-F75U digital camera mounted on a Leica MZ16 stereomicroscope and an Olympus QColor3 camera mounted on an Olympus SZX10 stereomicroscope. The final images were generated using the freely available software CombineZM (<http://www.hadleyweb.pwp.blueyonder.co.uk/>) for the cases and genitalia.

Descriptions

Hypasmocoma laysanensis Schmitz and Rubinoff, sp. nov. Figs. 1, 12, 20

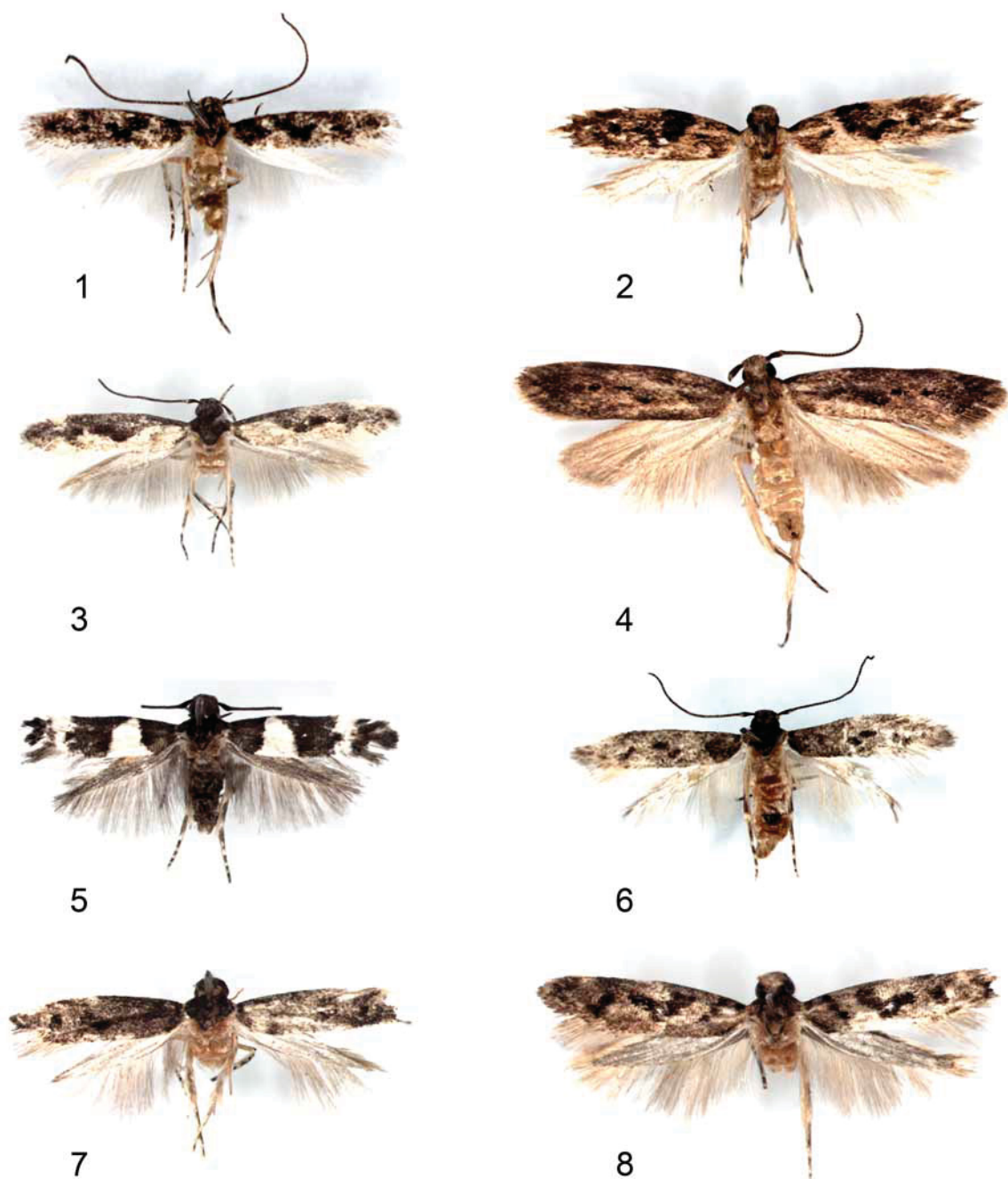
Material examined. Holotype ♂: [1] 'H[AWAI]I: Laysan, Guano Rock | "cone" case, III-25-[20]08 | em[ergence]. VI-17-[20]08, #DR07C22 | *leg[it]*. C[ynthia]. King'; [2] 'HOLOTYPE | *Hypasmocoma* |

laysanensis | Schmitz and Rubinoff". Specimen in perfect condition. Deposited in the UHIM. **Paratypes:** 46 ♂, 44 ♀, from Laysan Island, Hawaii, USA; 4 ♂, 5 ♀, with same data as holotype except date of emergence: IV-2-[20]08 (2 ♂), IV-8-08 (1 ♂), IV-16-08 (1 ♂, 5 ♀); 1 ♀, HI: Laysan, Guano Rock, Camp Pritchardia, "cone case", III-24-08, em. IV-2-08, #DR08C21, *leg.* C. King; 1 ♀, HI: Laysan, Guano Rock, "cone case", III-25-08, em. IV-28-08, #DR08C23A, *leg.* C. King; 1 ♂, HI: Laysan, Guano Rock, "cone case", III-25-08, em. IV-28-08, #DR08C24A, *leg.* C. King; 38 ♂, 33 ♀, HI: Laysan, Guano Rock, "cone case", IX-19-[20]07, em. IX-27-07 (1 ♀), IX-28-07 (1 ♂), X-3-07 (2 ♂, 2 ♀, one dissected PS124), X-8-07 (2 ♂, 2 ♀), X-11-07 (1 ♀), X-13-07 (2 ♀, one dissected PS125), X-15-07 (1 ♂, 1 ♀), X-22-07 (1 ♀), X-26-07 (1 ♂, 1 ♀), X-27-07 (1 ♂, 1 ♀), X-29-07 (2 ♂), X-30-07 (1 ♀), X-31-07 (1 ♂, 1 ♀), XI-2-07 (1 ♂, 2 ♀), XI-5-07 (5 ♂, 6 ♀), XI-6-07 (3 ♂, 4 ♀), XI-7-07 (4 ♂), XI-8-07 (1 ♂, 2 ♀), XI-9-07 (1 ♀), XI-13-07 (3 ♂, 2 ♀), XI-15-07 (2 ♂, 2 ♀), XI-24-07 (2 ♂), XI-27-07 (1 ♂, dissected PS122), XI-30-07 (1 ♂), XII-5-07 (1 ♂), XII-17-07 (1 ♂, dissected PS121), I-7-08 (1 ♂), II-19-08 (1 ♂), #DR07I2E, *leg.* C[indy]. Rehkemper; 2 ♂, 4 ♀, HI: Laysan, Guano Rock, "cone case", IX-15-07, em. X-17-07 (1 ♀), X-29-07 (1 ♀), X-31-07 (1 ♂, dissected PS123, 1 ♀), XI-5-07 (1 ♀), XI-6-07 (1 ♂), #DR07I2D, *leg.* M[like]. Richardson; 1 ♂ (dissected PS123), HI: Laysan, Guano Rock, "cone case", IX-15-07, em. XI-7-07 (1 ♂), #DR07I2C, *leg.* M. Richardson. Deposited in BPBM, MHNG, UHIM, and USNM.

Diagnosis. Among all the species of *Hypsmocoma* from the NWHI, *H. laysanensis* can be easily separated by the combination of its size, distinct pattern, and coloration. The species is relatively small compared to the others inhabiting this remote island chain (wingspan between 5.2 and 7.7 mm). Also, the spotted pattern and the beige-brown coloration that confer excellent camouflage to the resting adult on the sandy background found on Laysan Island are unique for the NWHI *Hypsmocoma*.

Description. Male (n=47) (Figs. 1, 12). Wingspan 5.2–7.7 mm (Holotype: 7.0 mm). Head with brown-tipped beige scales converging toward midline on occiput. Base of haustellum with beige and dark-brown scales. Maxillary palpus reduced. Labial palpus recurved upward with off-white scales ventrally and dark-brown scales dorsally, off-white ring apically on second segment, and long slender dark-brown third segment with sometimes sparse off-white scales at base. Antennal flagellum dark brown, with off-white ring at apex on first flagellomere; scape mostly dark brown with off-white scales ventrally and forming ring apically, antennal pecten present consisting of three thin setae. Thorax mostly dark brown with brown-tipped beige scales at collar and apex of tegula; metascutellum beige. Foreleg dark brown with off-white ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs off-white. Hindleg as midleg, but more grayish brown and with off-white rings at apex of tarsomeres I–V. Forewing basally mostly dark brown with three more or less distinct dark-brown markings as a postbasal patch above midline, another submedian patch under midline, and a spot medially on midline, often joined together, reaching 0.5 length of forewing, and usually disconnected from basal patch; otherwise with brown-tipped beige scales, sometimes dense enough to appear as dark-brown spots in middle of postmedian and submarginal regions. Hindwing and fringe off-white. Subcostal brush absent. Abdomen dorsally uniform beige; ventrally off-white, with tuft of long off-white scales on each side of genitalia. Sclerotized ring strongly developed across entire sternum VII with sclerotized hook arising on right side (pseuduncus *sensu* Zimmerman 1978), elongate, slightly curved at apex, large basally and narrowing apically to blunt apex. Genital flaps (epiptygmata *sensu* Zimmerman 1978), membranous, rounded, broad and thin, arising on both sides apically of sclerotized sternum VIII.

Male genitalia (n=3) (Fig. 12). Uncus and gnathos absent, but replaced by uncuslike processes attached to tegumen (brachia *sensu* Zimmerman 1978); right process elongate, curved ventrally, apically pointed, about 6 X length of left process. Tegumen wide, heavily sclerotized, dorsoventrally flattened. Valvae symmetrical, each forming long and slender arm slightly bent upward adorned with setae disposed comblike along dorsal margin, slightly broadened distally, with three sclerotized spurlike setae sequentially longer distally on each valva, the setae on left valva being 4–5 X length of minute setae on right valva. Phallus slightly bent to right, stout, blunt-tipped, heavily sclerotized, slightly down curved; vesica without spines or cornuti. Anellus with two symmetrical lobes, thin until apex, both adorned with small setae, with two or three very long setae at apex.



FIGURES 1–8. Holotypes of *Hyposmocoma* spp., adult males. 1. *H. laysanensis*; 2. *H. ekemamao*; 3. *H. opuimaloo*; 4. *H. mokumana*; 5. *H. nihoa*; 6. *H. kikokolu*; 7. *H. menehune*; 8. *H. papahanau*.

Female (n=44). Wingspan 6.4–7.3 mm. Frenulum with 3 acanthae. Antennae slightly thinner than that of male. Otherwise externally like males.

Female genitalia (n=2) (Fig. 20). Papillae anales short, lightly sclerotized and setose, slightly longer than wide. Anterior and posterior apophyses thin and straight, posterior apophyses about 2.5 X length of anterior apophyses. Ostium bursae heavily sclerotized, externally protruding, snailshell shaped with broad base. Ductus bursae long and of narrow girth. Corpus bursae oval and elongate, with light scobination; signum absent. Inception of ductus seminalis very enlarged, cylindrical, situated at posterior end of corpus bursae. Apical margin of tergum VIII with broad emargination medially.

Larval case (n=529). Cone-shaped structure, 4.5–6.0 mm in length, small and thin, decorated with bits of sand, and probably guano, woven with silk filaments; aperture covered with operculum decorated with small pebbles, or sand grains fastened by silk; background color ranging from off-white to gray.

Etymology. The name of *H. laysanensis* is derived from that of the type locality, the island of Laysan.

Biology. All adults were reared from case-making larvae. Larvae were collected during the day on rocks, the latter sometimes disposed in a pile, on the island of Laysan in March and September. When disturbed, larvae were observed to tightly close the operculum of their case with their mandibles. The abundance of the cases suggests that the species is very common on Laysan. Parasitoids were reared from some larvae and have been identified as belonging to the Eupelmidae (n=5) and Pteromalidae (n=2) (Insecta: Hymenoptera). Most species of cone-cased bearing *Hyposmocoma* in the younger main Hawaiian Islands live in streams and are aquatic (Rubinoff 2008), making the dry habitat of this species unusual.

Distribution. Known only from the NWHI of Laysan where it is presumed to be endemic.



FIGURES 9–11. Case types of *Hyposmocoma* spp., larvae. 9. Cone case type of *H. opuumaloo*; 10. Purse case type of *H. mokumana*; 11. Burrito case type of *H. nihoa*.

***Hyposmocoma ekemamao* Schmitz and Rubinoff, sp. nov. Figs. 2, 13, 21, 27**

Material examined. Holotype ♂ (dissected, slide PS138): [1] ‘H[AWAI]I: Laysan, Guano Rock | “purse” case, IX-15-[20]07 | em[ergence]. XI-15-[20]07, #DR07I2H | leg[it]. C[indy]. Rehkemper’; [2] ‘HOLOTYPE | *Hyposmocoma* | *ekemamao* | Schmitz and Rubinoff’. Specimen in good condition except for broken antennae and labial palpi. Deposited in the UHIM. **Paratype:** 1 ♀ (dissected, slide PS139), from Laysan Island, Hawaii, USA; HI, Laysan, Guano Rock, “purse” case, III-27-[20]08, em. IV-17-08, #DR07C24C, leg. C[ynthia]. King’. Deposited in the UHIM.

Diagnosis. *Hyposmocoma ekemamao* is a relatively large beige species (wingspan between 10.0 and 10.5 mm). It could be confused in the NWHI only with *H. mokumana* which is also mostly beige, but has more contrasting markings, is larger, and occurs only on Necker Island.

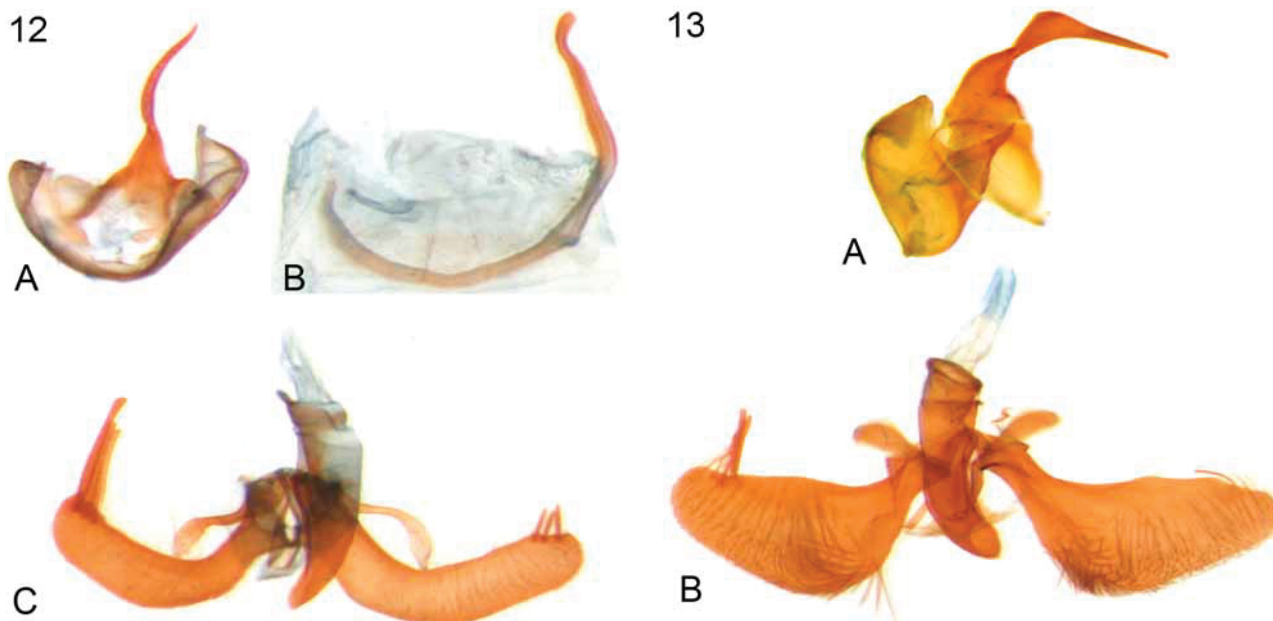


FIGURE 12. Male genitalia of *Hyposmocoma laysanensis* from specimen on slide PS122. A. Tegumen, ventral aspect; B. Sclerotized hook on abdominal segment VII, ventral aspect; C. Valvae with phallus, ventral aspect.

FIGURE 13. Male genitalia of *Hyposmocoma ekemamao* from specimen on slide PS138. A. Tegumen, lateral aspect; B. Valvae with phallus, ventral aspect.

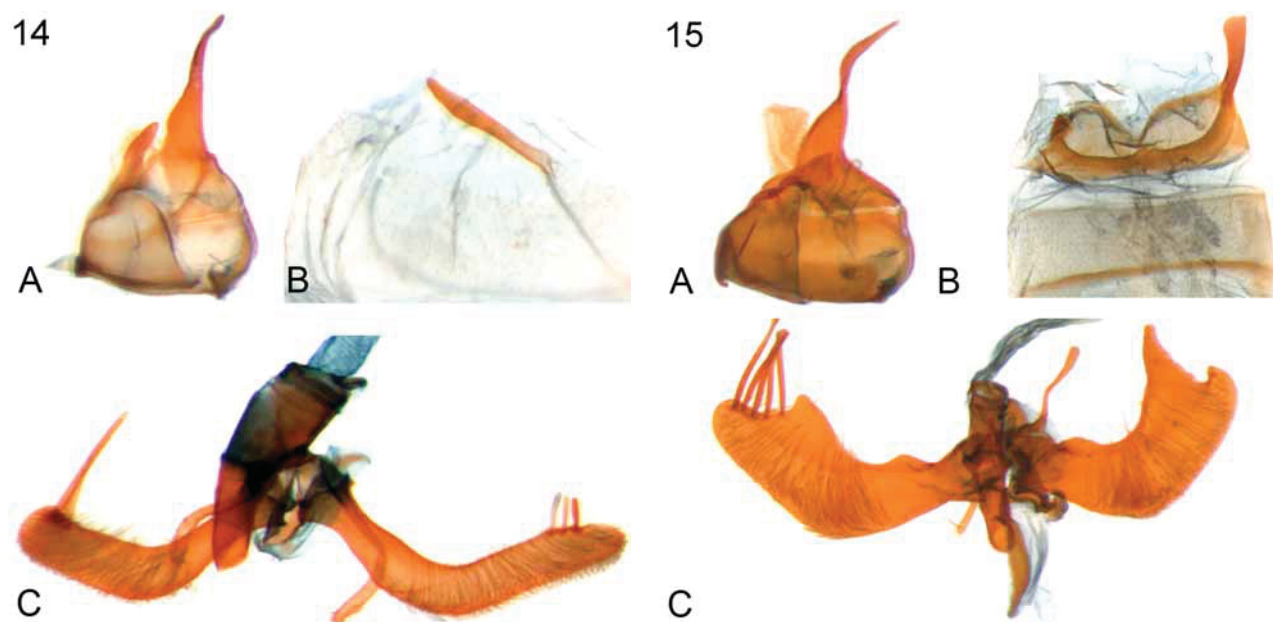


FIGURE 14. Male genitalia of *Hyposmocoma opuumaloo* from specimen on slide PS132. A. Tegumen, ventral aspect; B. Sclerotized hook on abdominal segment VII, ventral aspect; C. Valvae with phallus, ventral aspect.

FIGURE 15. Male genitalia of *Hyposmocoma mokumana* from specimen on slide PS172. A. Tegumen, ventral aspect; B. Sclerotized hook on abdominal segment VII, ventral aspect; C. Valvae with phallus, ventral aspect.

Description. Male (n=1) (Fig. 2). Wingspan 10.0 mm (holotype). Head mostly pale beige on occiput becoming off-white on vertex and frons. Base of haustellum with pale-beige scales. Maxillary palpus reduced. Thorax and tegula with dark-brown-tipped pale-beige scales; metascutellum pale beige. Foreleg coxa pale beige; femur gray brown; tibia and tarsomeres gray brown with pale-beige ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs pale beige. Hindleg as midleg, pale-beige rings at

apex on tarsomeres I–V. Forewing mostly pale beige with dark-brown-tipped scales sometimes dense enough to appear as dark-brown area, with dark-brown markings as a median patch above midline reaching costal margin, line starting from bottom of patch undulating anteriorly along midline, and postmedian spot separated from apex of line by the pale-beige area. Hindwing and fringe off-white. Subcostal brush absent. Abdomen dorsally pale beige; ventrally off-white, with tuft of off-white long scales on each side of genitalia. Sclerotized hook of sternum VII absent. Genital flaps rounded, elongated and thin, arising on both sides at apex of sclerotized sternum VIII.

Male genitalia (n=1) (Fig. 13). Right uncuslike process sickle shaped, very long, about 6 X length of left process, slightly twisted. Tegumen wide, heavily sclerotized, dorsoventrally flattened. Valvae symmetrical, with long arms medium width, bent upward at right angle and enlarged postbasally in middle, adorned with setae disposed comblike along dorsal margin, distally with five sclerotized spurlike setae on left valva, the outer seta being thinner than the other four distant larger setae of same length, and only one thin spurlike seta on right valva. Phallus stout, blunt tipped, heavily sclerotized, open ventrally, and bent downward at right angle at about 2/3 of length; vesica without spines or cornuti. Anellus with two symmetrical lobes, thin until apex, both adorned with small setae, with long setae on apex.

Female (n=1) (Fig. 27). Wingspan 10.5 mm. Frenulum with 3 acanthae. Head mostly covered with smooth cream-colored scales. Labial palpus recurved, first two segments pale beige, third segment dark brown with some pale-beige scales. Antennal flagellum dark brown, pale-beige ring at apex on first 8 flagellomeres; scape dark brown with pale-beige ring apically, antennal pecten absent. Forewing background creamy with fewer dark-brown-tipped scales than male, thus cream areas appearing scattered on forewing, dark-brown markings less contrasting than in males. Otherwise externally like males.

Female genitalia (n=1) (Fig. 21). Papillae anales short, lightly sclerotized and setose, slightly longer than wide. Anterior and posterior apophyses thin and straight, posterior apophyses about 3 X length of anterior apophyses. Ostium bursae heavily sclerotized, externally protruding, snailshell shaped curled to the left, with base of same girth. Ductus bursae long and thin. Corpus bursae oval and elongate, with light scobination; signum absent. Inception of ductus seminalis enlarged, cylindrical, situated at posterior end of corpus bursae. Apical margin of tergum VIII without medial emargination.

Larval case (n=18). Purse-shaped, 4.1–7.0 mm in length, smooth and cylindrical, bulged and flat in middle, with growth lines starting at middle and extending laterally toward two entrances; background color shiny dark brown.

Etymology. The name of *H. ekemamao*, from the Hawaiian, *eke*, bag, refers to the purselike case of this species, and *mamao*, remote, refers to the remote position of Laysan in the NWHI chain.

Biology. Adults were reared from case-making larvae. Larvae were collected on the ground during the day on the island of Laysan in September away from shoreline.

Distribution. Known only from the NWHI of Laysan where it is presumed to be endemic.

Remarks. The case collected by Fullaway (1914) on Laysan Island may belong to this species. On the right valva of the single available male the presence of a socket near the thin spurlike seta could indicate another spurlike seta, which was lost before dissection.

***Hyposmocoma opuumaloo* Schmitz and Rubinoff, sp. nov. Figs. 3, 9, 14, 22, 28**

Material examined. Holotype ♂ (dissected, slide PS132): [1] ‘H[AWAI]I: Necker, Flagpole Hill | “cone” case, VI-23-[20]07 | em[ergence]. VIII-20-[20]07, #DR07F3I | *leg[it]*. C[indy]. Rehkemper’; [2] ‘HOLOTYPE | *Hyposmocoma* | *opuumaloo* | Schmitz and Rubinoff’. Specimen in good condition except for broken antennae and left labial palpus. Deposited in the UHIM. **Paratypes:** 2 ♀ (dissected, slide PS134), from Necker Island, Hawaii, USA, with same data as holotype except date of emergence: VIII-16-[20]07, IX-13-04. Deposited in the UHIM.

Diagnosis. *H. opuumaloo* is somewhat similar in wing pattern to *H. papahanau*. The two species can be easily separated by the presence in *H. opuumaloo* of a cream area on the inner margin of the forewings and a patch of dark-brown scales at the base of the hindwings. Also, males of *H. opuumaloo* possess a sclerotized hook on abdominal segment VII. Also, *H. opuumaloo* is endemic to the island of Necker and *H. paphana* is found only on the island of Nihoa.

Description. Male (n=1) (Figs. 3, 14). Wingspan 9.1 mm (holotype). Head mostly grayish-brown on occiput becoming off-white on vertex and frons. Base of haustellum with white scales. Maxillary palpus reduced. Recurved labial palpus grayish brown dorsally and off-white ventrally, with some sparse grayish-brown scales on second and third segment apically. Antennal flagellum dark brown, with off-white ring at apex on first flagellomere; scape dark brown with off-white scales ventrally and forming ring apically, antennal pecten made of five thin setae. Thorax and tegula dark brown; metascutellum pale beige. Foreleg coxa beige; femur dark brown; tibia and tarsomeres dark brown with off-white ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs off-white. Hindleg as midleg, but ground color more silver gray, with off-white rings at apex on tarsomeres I–V. Forewing grayish brown, with crescent-shaped band basally and costal margin slightly darker, cream area on inner half of forewing with some dark-brown-tipped off-white scales; dark-brown markings as a wavelike median patch along midline and somewhat fused with upper grayish-brown area, and postmedian spot separated from median patch by cream area; cream markings as notch subapically on costal margin and another opposite on inner margin. Hindwing gray with some dark-brown scales at base of inner margin; grayish-beige fringe. Subcostal brush absent. Abdomen dorsally pale beige; ventrally off-white, with tuft of long off-white scales on each side of genitalia. Sclerotized hook small with indistinct sclerotized ring on segment VII.

Male genitalia (n=1) (Fig. 14). Uncuslike processes with right process elongate, curved ventrally, apically pointed, adorned with small crest mediodorsally at 1/3 of length to apex, about 4 X length of left process. Tegumen wide, heavily sclerotized along margins, dorsoventrally flattened. Valvae symmetrical, forming long and slender arms, as wide as long, bent upward at almost right angle medially, adorned with setae disposed comblike along dorsal margin, with three sclerotized spurlike setae sequentially longer distally on each valva, setae on left valva about 4–5 X length of smaller setae on right valva. Phallus large, heavily sclerotized, slightly bent to right, blunt tipped, with large bulbous base; vesica without spines or cornuti. Anellus with two symmetrical lobes, thin, angled upward, adorned with small setae until apex, and without longer apical setae.

Female (n=1) (Fig. 28). Wingspan 8.9 mm. Frenulum with 3 acanthae. Head mostly with beige smooth scales. Forewing gray with brown-tipped scales dense enough apically to appear as brown patch; cream to off-white area on inner half larger basally; with some scattered rusty-brown scales; dark-brown markings as crescent shaped band basally, another along 1/3 length of costal margin, a median patch undulating along midline and a postmedian spot separated from the median patch by cream area; rusty-brown markings as a notch subapically on costal margin and another opposite on inner margin, connected by a thin V-shaped subapical off-white line. Otherwise externally like males.

Female genitalia (n=1) (Fig. 22). Papillae anales short. Apophyses thin and straight; posterior apophyses about 2.5 X length of anterior apophyses. Ostium bursae heavily sclerotized and very large, externally protruding, snailshell shaped curled to the left, with broad base. Ductus bursae long and of small girth. Corpus bursae oval and elongate, with light scobination; signum absent. Inception of ductus seminalis very enlarged, cylindrical, situated at posterior end of corpus bursae. Apical margin of tergum VIII with broad U-shaped emargination medially forming a bowl encompassing ostium with patches of dense scales situated laterally.

Larval case (n=113) (Fig. 9). Cone-shaped, 6.7–7.1 mm in length, small and thin, decorated with bits of sand woven with silk filaments; operculum decorated with small pebbles; case background color ranging from gray to brown.

Etymology. From the Hawaiian *ōpu'u*, cone, and *malo'o*, dry, referring to the type of case and habitat of this species.

Biology. Adults were reared from case-making larvae. Larvae were collected on the ground during the day on the island of Necker in June. Most species of cone cased *Hyposmocoma* in the younger and higher Hawaiian Islands are aquatic (Rubinoff 2008), making the dry habitat of this species unusual.

Distribution. Known only from the NWHI of Necker where it is presumed to be endemic.

Remarks. This species may represent the new species 28 of Zimmerman (1978) collected on Necker Island based on characters like absence of subcostal brush, presence of sclerotized hook, male genitalia, and thornlike larval case.

***Hyposmocoma mokumana* Schmitz and Rubinoff, sp. nov. Figs. 4, 10, 15, 23**

Material examined. Holotype ♂: [1] ‘H[AWAI]I: Necker, Annexation Hill, elev[ation]. 60m[eters] | in *Sesbania* litter, “purse” case, IX-4-[20]04 | em[ergence]. I-22-[20]05, #DR04I1 | *leg[it]*. S[teve]. Montgomery’; [2] ‘HOLOTYPE | *Hyposmocoma* | *mokumana* | Schmitz and Rubinoff’. Specimen in good condition except for left broken antenna and broken labial palpi. Deposited in the UHIM. **Paratypes:** 1 ♂ (dissected, slide PS172), 4 ♀ (one dissected, slide PS126), from Necker Island, Hawaii, USA, with same data as holotype except date of emergence: I-25-[20]08 (3♀), II-25-08 (♂). Deposited in the UHIM.

Diagnosis. Among the species of *Hyposmocoma* from the NWHI, *H. mokumana* can be easily distinguished by its large size (wingspan between 11.4 and 14.3 mm). The purse-shaped cases are also larger than those of *H. ekemamao* (4.1–7.0 mm in length, compared to 7.4–8.9 mm for *H. mokumana*). Also, each is endemic to a single island.

Description. Male (n=2) (Figs. 4, 15). Wingspan 11.4–12.5 mm (Holotype: 11.4 mm). Head mostly pale beige. Base of haustellum with pale-beige scales. Maxillary palpus reduced. Antennal flagellum dark brown; scape dark brown with pale-beige ring at apex. Thorax and tegula pale beige with dark-brown-tipped pale-beige scales; metascutellum pale beige. Foreleg coxa pale beige; femur dark brown; tibia and tarsomeres gray brown with pale-beige ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs pale beige. Hindleg pale beige and grayish tarsomeres with pale-beige rings at apex on tarsomeres I–V. Forewing background pale beige and mostly covered with dark-brown-tipped scales sometimes dense enough to appear as dark-brown area; dark-brown markings as a median thin line starting undulating anteriorly along midline, and another postmedian spot separated from apex of line by background color. Hindwing and fringe uniformly beige. Subcostal brush absent. Abdomen dorsally shiny beige; ventrally off-white, with tuft of long scales on each side of genitalia shiny beige. Sclerotized ring very large and strongly developed across entire sternum with sclerotized hook short and large on entire length until enlarged blunt apex; minute sclerotized point on left side with blunt apex. Tergum VII with two large strongly sclerotized flaps joined in the middle. Sterna V, VI, and VII with sclerotized anterior margins. Genital flaps rounded, elongated and thin; arising on both sides apically of sclerotized sternum VIII.

Male genitalia (n=1) (Fig. 15). Uncuslike processes with right process sickle shaped, very long, about 6 X length of left process, slightly twisted. Tegumen wide, heavily sclerotized, dorsoventrally flattened. Valvae symmetrical, with long arms of large width, bent upward at right angle in the middle, with basal small rounded projection (slightly larger on right valva) and subapical large triangular projection (slightly more elongated on right valva), adorned with setae disposed comblike on inner surface of dorsal margin, with absence of sclerotized spurlike seta on right valva (but presence of sockets), and five sclerotized spurlike setae sequentially longer distally on left valva. Phallus stout, blunt tipped, heavily sclerotized, and bent downward at about middle of length; vesica without spines or cornuti. Anellus with two symmetrical lobes, thin until apex, both adorned with small setae, setose on apex adorned with one long setae.

Female (n=4). Wingspan 13.8–14.3 mm. Head mostly grayish brown with grayish-brown-tipped beige scales around eye. Base of haustellum with beige scales. Maxillary palpus reduced. Recurved labial palpus grayish brown dorsally and beige ventrally; third segment slender and grayish brown. Antennal flagellum grayish brown; scape grayish brown with brown scales forming ring apically. Thorax and tegula mostly

grayish brown with scattered beige scales; metascutellum pale beige. Foreleg coxa and femur grayish brown; tibia and tarsomeres brown with beige ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs beige. Hindleg as midleg, but ground color more grayish beige, with beige rings at apex on tarsomeres I–V. Forewing mostly grayish brown, with pale beige to rusty-beige inner half; dark-brown markings as submedian and postmedian spots at midline, a median V-shaped line in between these two spots and of same width in middle of wing, and as notch subapically on costal margin and another opposite on inner margin. Abdomen shiny beige. Hindwing and fringe silverish off-white. Frenulum with three acanthae.

Female genitalia (n=1) (Fig. 23). Papillae anales very short and setose. Anterior and posterior apophyses thin and straight, slightly enlarged at posterior end, posterior apophyses about 2.5 X length of anterior apophyses. Ostium bursae very small, heavily sclerotized, externally protruding, and snailshell shaped curled left. Ductus bursae long and of small girth. Corpus bursae oval and elongate, with light scobination; signum absent. Inception of ductus seminalis very much enlarged, cylindrical, situated at posterior end of corpus bursae. Apical margin of tergum VIII without emargination medially.

Larval case (n=10) (Fig. 10). Purse-shaped, 7.4–8.9 mm in length, smooth and cylindrical, bulged and flat medially, with growth lines starting at middle and extending toward two entrances situated laterally; background color is brown.

Etymology. The name *mokumana* is short for Mokumanamana which is the Hawaiian name for Necker Island.

Biology. Adults were reared from case-making larvae. Cases were collected in *Sesbania* litter (Fabaceae) during the day on the island of Necker in September.

Distribution. Known only from the NWHI of Necker where it is presumed to be endemic.

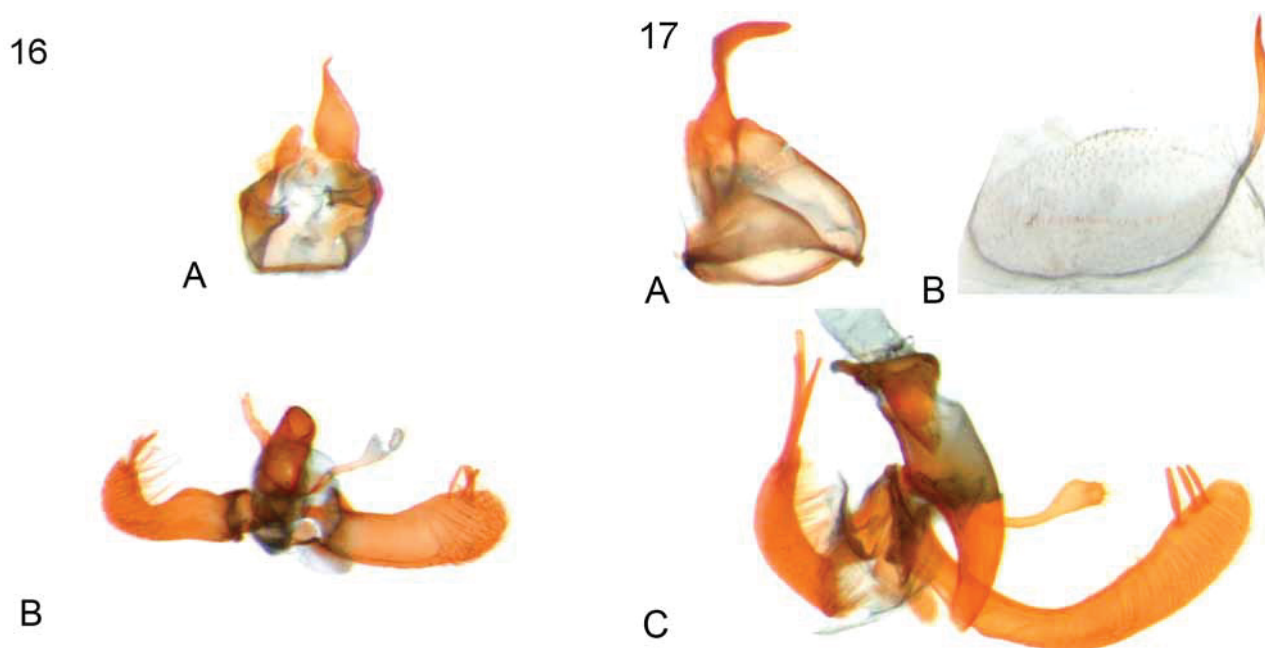


FIGURE 16. Male genitalia of *Hyposmocoma nihoa* from specimen on slide PS140. A. Tegumen, ventral aspect; B. Valvae with phallus, ventral aspect.

FIGURE 17. Male genitalia of *Hyposmocoma kikokolu*. A. Tegumen (slide PS129), lateral aspect; B. Sclerotized hook on abdominal segment VII (slide PS129), ventral aspect; C. Valvae with phallus (slide PS141), ventral aspect.

Hyposmocoma nihoa Schmitz and Rubinoff, sp. nov. Figs. 5, 11, 16, 24

Material examined. Holotype ♂: [1] ‘H[AWAI]I: Nihoa, Miller Canyon | “burrito” case, VII-17-[20]07 | em[ergence]. VIII-16-[20]07, #DR07G8 | *leg[it]*. D[aniel]. Rubinoff, J[esse]. Eiben’; [2] ‘HOLOTYPE |

Hyposmocoma | *nihoa* | Schmitz and Rubinoff⁷. Specimen in perfect condition except for broken antennae. Deposited in the UHIM. **Paratypes:** 3 ♂, 2 ♀, from Nihoa Island, Hawaii, USA; 3 ♂, with same data as holotype except date of emergence: IX-24-[20]07 (1 ♂), IX-28-07 (1 ♂, dissected, slide PS131), X-11-07 (1 ♂, dissected, slide PS140); 2 ♀ (one dissected, slide PS133), with same data as holotype except date of emergence: VIII-8-07, and rearing log number: #DR07G10. Deposited in BPBM and UHIM.

Diagnosis. Among the known species of *Hyposmocoma* from the NWHI and within the genus, the black and off-white forewing markings of *H. nihoa* are unique (see Fig. 5).

Description. *MALE* (n=4) (Fig. 5). Wingspan 6.3–7.2 mm (Holotype: 7.1 mm). Head with large black scales flattened on vertex, replaced on frons by small dark-brown scales. Base of haustellum with black scales. Maxillary palpus reduced. Labial palpus recurved, with off-white scales ventrally and black scales dorsally. Antennal flagellum and scape black, sometimes with off-white scales at base of first flagellomeres; antennal pecten made of three thin setae. Thorax mostly black, with some off-white scales distributed on outer margins, metascutellum dark gray. Foreleg coxa and femur with a mixture of off-white and black scales; tibia and tarsomeres black with off-white ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs off-white. Hindleg as midleg, but with off-white rings at apex of tarsomeres I–V. Forewing mostly black with bluish-green tinge, off-white markings as postbasal triangle with point reaching about 1/4 costa and base between 1/5 and 2/5 on inner margin, and narrower transverse postmedian band of variable width at about 3/4 forewing length. Hindwing gray with grayish-beige fringe. Subcostal brush present on dorsal surface of inner margin as a tuft of long dark-gray scales arising over conspicuous orange spot (not visible on Fig. 5) extending 1/3 length of hindwing. Abdomen dorsally uniform shiny dark gray; ventrally off-white, with tuft of long dark gray scales on each side of genitalia. Sclerotized hook of segment VII absent. Genital flaps rounded, elongated and thin; sternum VIII fused dorsally as a band, forming encompassing hull around tegumen.

Male genitalia (n=1) (Fig. 16). Right uncuslike process thick and large, sickle shaped, about 4 X length of left process; left process membranous. Tegumen wide, heavily sclerotized, dorsoventrally flattened. Valvae asymmetrical, with three sclerotized spurlike setae of same length on each valva; right valva spoon shaped, broader, and rounded distally, slightly upcurved and adorned with setae only on apical margin; left valva narrower, more strongly upturned from middle, with low rounded bump on dorsal margin subbasally. Phallus slightly bent to right, stout, blunt tipped, heavily sclerotized, open ventrally, and slightly angled downwards; vesica without spines or cornuti. Anellus with two thin symmetrical lobes adorned with small setae, with very long setae at apex.

Female (n=2). Wingspan 7.6 mm. Frenulum with 3 acanthae. Postmedian off-white band less conspicuous than for male. Otherwise externally like males.

Female genitalia (n=1) (Fig. 24). Papillae anales short, lightly sclerotized and setose, slightly longer than wide. Anterior and posterior apophyses thin and straight, posterior apophyses about 2.5 X length of anterior apophyses. Ostium bursae relatively small, heavily sclerotized, externally protruding, snailshell shaped curled to left, with base slightly larger. Ductus bursae long and thin. Corpus bursae oval and elongate, with light scobination; signum absent. Inception of ductus seminalis enlarged, cylindrical, situated at posterior end of corpus bursae. Apical margin of tergum VIII without medial emargination.

Larval case (n=23) (Fig. 11). Burrito-shaped (for a definition, see Schmitz & Rubinoff 2008), 3.4–4.8 mm in length, large and rounded with curved pointed distal end, decorated with lichens woven with silk filaments; case background color ranging from green to gray.

Etymology. The name of *H. nihoa* is derived from that of the type locality, the island of Nihoa.

Biology. Adults were reared from case-making larvae. Larvae were collected during the day in July on small bushes and rocks on the island of Nihoa.

Distribution. Known only from the NWHI of Nihoa where it is presumed to be endemic.

***Hyposmocoma kikokolu* Schmitz and Rubinoff, sp. nov. Figs. 6, 17, 25**

Material examined. Holotype ♂: [1] ‘H[AWAI]I: Nihoa, Miller Canyon | “cone” case, VII-17-[20]07 | em[ergence]. IX-5-[20]07, #DR07G6 | leg[it]. D[aniel]. Rubinoff, J[esse]. Eiben’; [2] ‘HOLOTYPE | Hyposmocoma | kikokolu | Schmitz and Rubinoff’. Specimen in perfect condition. Deposited in the UHIM.

Paratypes: 6 ♂, 7 ♀ from Nihoa Island, Hawaii, USA: 2 ♂, 4 ♀, with same data as holotype except date of emergence: VIII-22-[20]07 (1 ♂, 1 ♀), VIII-27-07 (1 ♀), IX-2-07 (1 ♀ dissected, slide PS128), IX-4-07 (1 ♀), IX-13-07 (1 ♂, dissected, slide PS130); 3 ♂, 3 ♀, with same data as holotype except date of emergence and rearing log number: VIII-28-07, #DR07G9 (1 ♂, dissected, slide PS141); IX-4-07, #DR07G2 (1 ♂); IX-7-07, #DR07G9 (1 ♂); IX-10-07, #DR07G2 (1 ♂, dissected, slide PS129; 1 ♀, dissected, slide PS127); X-5-07, #DR07G2 (1 ♀); X-11-07, #DR07G9 (1 ♀). Deposited in BPBM, MHNG, UHIM, and USNM.

Diagnosis. *Hyposmocoma kikokolu* is a mostly uniform grayish-brown species. Based on external characters *H. kikokolu* can be separated from the closest looking species, *H. menehune*, by its larger size (wingspan between 8.0 and 10.0 mm vs 7.2 and 7.4 mm), and the thinner sclerotized hook in males. The two species are also allopatric. The genitalia are diagnosed in the treatment of *H. menehune*.

Description. Male (n=6) (Figs. 6, 17). Wingspan 8.0–10.2 mm (Holotype: 9.5 mm). Head mostly grayish brown with dark-brown scales on each side, and beige to reddish-brown scales around eyes, with few, if any, reddish-brown and off-white scales on base of occiput; larger smooth grayish-brown to whitish-brown scales on vertex, replaced on the frons by smaller off-white scales. Base of haustellum with off-white scales. Maxillary palpus reduced. Labial palpus slender and recurved with off-white scales ventrally and dark brown scales dorsally. Antennal flagellum dark gray with apical off-white ring on first 5–12 flagellomeres; scape dark gray with off-white scales ventrally and forming ring apically, antennal pecten present with row of 5 or 6 thin setae. Thorax mostly dark brown, with some grayish-brown scales on lateral margins; tegulae with a mixture of grayish-brown and dark-brown scales; metascutellum silver gray. Foreleg dark brown with off-white ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs off-white. Hindleg as midleg, but more grayish brown and with off-white rings at apex of tarsomeres I–V. Forewing base dark brown otherwise wing mostly covered with grayish-brown-tipped off-white scales; dark brown markings as pair of oblong spots medially, disconnected from each, with most basal spot below other, and more or less conspicuous small spot postmedially on midline; off-white markings as small notch subapically on costa and another opposite on inner margin. Hindwing and fringe uniformly silver-gray. Subcostal brush absent. Abdomen dorsally silver-gray; ventrally off-white, with tuft of long off-white scales on each side of genitalia. Sclerotized hook of segment VII elongate, very slightly curved, large basally and narrowing apically to acute apex arising from thin sclerotized ring. Genital flaps membranous, rounded, large, and thin, arising on both sides at apex of sclerotized sternum VIII.

Male genitalia (n=2) (Fig. 17). As for *H. opuumaloo*, except for bulbous anellus lobes at apex.

Female (n=7). Wingspan 9.0–10.0 mm. Frenulum with 3 acanthae. Antennae slightly thinner than that of male. Head, labial palpus, and thorax darker; metascutellum and first abdominal segment dark brown; ground color of forewing more dark gray. Otherwise externally like males.

Female genitalia (n=2) (Fig. 25). Papillae anales short. Anterior apophyses straight with slight angle at base; posterior apophyses thin and straight, about 2.5 X length of anterior apophyses. Ostium bursae heavily sclerotized and very large, externally protruding, snailshell shaped curled to the left, with broad base. Ductus bursae long and of small girth. Corpus bursae oval and elongate, with light scobination; signum absent. Inception of ductus seminalis very enlarged, cylindrical, situated at posterior end of corpus bursae. Apical margin of tergum VIII with broad U-shaped emargination medially forming a bowl encompassing ostium bursae with patches of dense scales situated laterally.

Larval case (n=318). Cone-shaped, 6.0–8.7 mm in length, small and thin, decorated with beige, brown, and black sand grains; operculum of case covered with small pebbles; background color ranging from gray to grayish brown.

Etymology. From the Hawaiian *kiko*, spot, and *kolu*, three, referring to the pattern of the forewing.

Biology. All adults were reared from case-making larvae. Larvae were collected on the ground during the day on the island of Nihoa in July. As noted, most cone-cased *Hypsmocoma* in the main Hawaiian Islands are aquatic (Rubinoff 2008), but streams do not exist in the NWHI.

Distribution. Known only from the NWHI of Nihoa, where it is presumed to be endemic.

Remarks. This species may represent the new species 28 of Zimmerman (1978), collected on Nihoa Island, based on characters such as absence of subcostal brush, presence of sclerotized hook, male genitalia, and thornlike larval case.

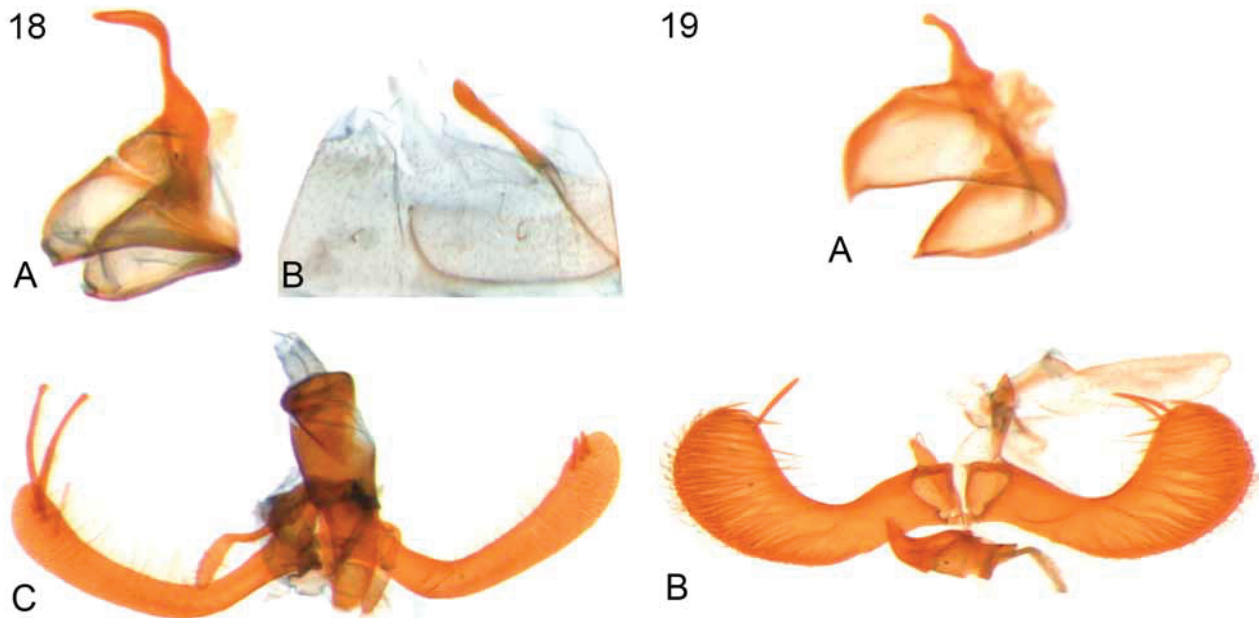


FIGURE 18. Male genitalia of *Hypsmocoma menehune* from specimen on slide PS135. A. Tegumen, lateral aspect; B. Sclerotized hook on abdominal segment VII, ventral aspect; C. Valvae with phallus, ventral aspect.

FIGURE 19. Male genitalia of *Hypsmocoma papahānau* from specimen on slide PS137. A. Tegumen, lateral aspect; B. Valvae with phallus, ventral aspect (outer spurlike setae of left valva lost and phallus broken).

***Hypsmocoma menehune* Schmitz and Rubinoff, sp. nov. Figs. 7, 18, 26**

Material examined. Holotype ♂ (dissected, slide PS135): [1] ‘H[AWAI]I: Nihoa, Miller Canyon | “burrito” case, VII-17-[20]07 | em[ergence]. VII-22-[20]07, #DR07G5 | leg[it]. D[aniel]. Rubinoff, J[esse]. Eiben’; [2] ‘HOLOTYPE | Hypsmocoma | menehune | Schmitz and Rubinoff’. Specimen in good condition except for broken antennae and labial palpi. Deposited in the UHIM. **Paratypes:** 1 ♀ (dissected, slide PS136) from Nihoa Island, Hawaii, USA, with same data as holotype except date of emergence: XI-1-[20]07. Deposited in the UHIM.

Diagnosis. *Hypsmocoma menehune* is a relatively small grayish species similar to *H. kikokolu* although smaller (see above Diagnosis of *H. kikokolu*). It differs from *H. kikokolu* in male genitalia by having the arms of the valvae thinner and longer, with minute spurlike setae on the right valva (these setae are longer in *H. kikokolu*), and in female genitalia by having the apical margin of tergum VIII with no medial emargination.

Description. Male (n=1) (Figs. 7, 18). Wingspan 7.4 mm (holotype). Head mostly grayish brown with rusty-beige scale tufts on each side at base of occiput. Base of haustellum with off-white scales. Maxillary palpus reduced. Thorax and tegulae mostly gray brown; metascutellum silver gray. Foreleg gray brown with off-white ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs off-white. Hindleg as midleg. Forewing mostly covered with gray-brown-tipped gray scales; dark-gray-brown markings as pair of spots medially, disconnected and situated on top of each other, and another small spot

postmedially on midline; off-white markings as a small notch subapically on costal margin and another opposite on inner margin. Hindwing and fringe uniformly silver gray. Subcostal brush absent. Abdomen dorsally silvergray; ventrally off-white, with tuft of long scales on each side of genitalia off-white. Sclerotized hook elongated, straight, apically enlarged with blunt apex arising from thin sclerotized ring. Genital flaps membranous, rounded, large, and thin, arising on both sides at apex of heavily sclerotized sternum VIII.

Male genitalia (n=1) (Fig. 18). Right uncuslike process elongate, curved ventrally, blunt apically, about 4 X length of left process. Tegumen wide, heavily sclerotized along margins, dorsoventrally flattened. Valvae symmetrical, long and slender, with same width until apex, bent upward at right angle before middle, adorned with setae disposed comblike along dorsal margin, with three long sclerotized spurlike setae of same length on left valva, first seta thinner and with three minute setae on right valva. Phallus large, heavily sclerotized, slightly pointed apically, with large bulbous base becoming gradually slender until apex; vesica without spines or cornuti. Anellus with two symmetrical lobes, with very thin arms, slightly enlarged from middle and adorned with small setae at apex.

Female (n=7). Wingspan 7.2 mm. Frenulum with 3 acanthae. Head and thorax darker than male with grayish-blue tinge. Antennal pecten made of two thin setae; ground color of forewing light-grayish blue, with markings darker than male, sometimes black, and terminal scales on termen black tipped. Otherwise externally like males.

Female genitalia (n=1) (Fig. 26). Papillae anales short. Anterior and posterior apophyses straight and very thin, posterior apophysis about 2.5 X length of anterior apophysis. Ostium bursae heavily sclerotized and very large, externally protruding, snailshell shaped curled to the left, with broad base. Ductus bursae long and of small girth. Corpus bursae oval and elongate, with light scobination; signum absent. Inception of ductus seminalis very enlarged, cylindrical, situated at posterior end of corpus bursae. Apical margin of tergum VIII without medial emargination.

Larval case (n=9). Burrito-shaped, 3.7–4.0 mm in length, similar to that of *H. nihoa*, but without distinctly curved pointed distal end.

Etymology. In the Hawaiian mythology, *menehune* represents a legendary race of small people who worked at night and lived far from the eyes of normal humans referring to the nocturnal case-bearing larvae of this species.

Biology. Adults were reared from case-making larvae. Larvae were collected on the ground during the day on the island of Nihoa in July.

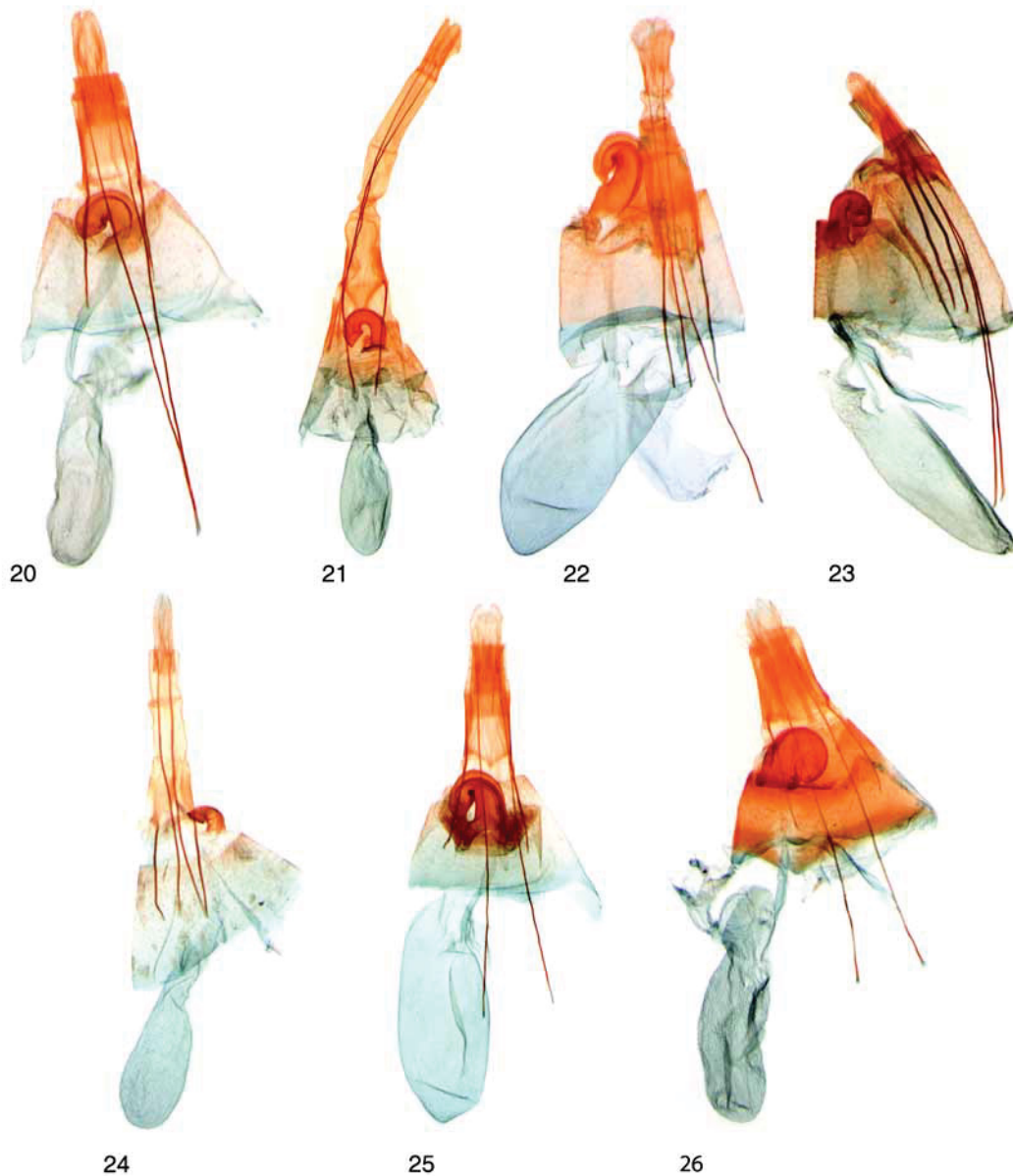
Distribution. Known only from the NWHI of Nihoa, where it is presumed to be endemic.

Hypsmocoma papahanau Schmitz and Rubinoff, sp. nov. Figs. 8, 19

Material examined. Holotype ♂ (dissected, slide PS137): [1] ‘H[AWAI]I: Nihoa, Miller Canyon | “burrito” case, VII-17-[20]07 | em[ergence]. VIII-20-[20]07, #DR07G4 | leg[it]. D[aniel]. Rubinoff, J[esse]. Eiben’; [2] ‘HOLOTYPE | Hypsmocoma | papahanau | Schmitz and Rubinoff’. Specimen in good condition except for broken antennae and labial palpi. Deposited in the UHIM.

Diagnosis. *H. papahanau* can be confused based on external characters only with the similar-looking *H. opuumaloo* in the NWHI but can be easily separated from the latter by the combination of wing pattern and coloration, and the absence of a sclerotized hook in males. The two species also occur allopatrically.

Description. **MALE** (n=1) (Fig. 8). Wingspan 8.8 mm (holotype). Head mostly rusty beige with dark-brown scales as tufts on each side at base of occiput. Base of haustellum with white scales. Maxillary palpus reduced. Thorax and tegula dark brown, with some scattered rusty scales; metascutellum pale beige. Foreleg coxa beige; femur dark brown; tibia and tarsomeres dark brown with off-white ring at middle and apex of tibia, and apex of tarsomeres I, II, and V. Midleg as foreleg, spurs off-white. Hindleg as midleg, but ground color more silver-gray, with off-white rings at apex on tarsomeres I–V. Forewing mostly covered with rusty-brown tipped beige scales dense enough to appear as band along dorsal margin with dark-brown scales at base



FIGURES 20–26. Female genitalia of *Hyposmocoma* spp., ventral aspect 20. *H. laysanensis* (slide PS124); 21. *H. ekemamao* (slide PS139); 22. *H. opuumaloo* (slide PS134); 23. *H. mokumana* (slide PS126); 24. *H. nihoa* (slide PS133); 25. *H. kikokolu* (slide PS127); 26. *H. menehune* (slide PS136).



27



28

FIGURES 27–28. Paratypes of *Hyposmocoma* spp., adult females. 27. *H. ekemamao*; 28. *H. opuumaloo*.

with grayish-brown scales forming interrupted band along costal margin and crescent shaped band before termen; dark-brown markings as a basal spot on the costal margin, a postbasal line extending diagonally from costal margin at 1/6 to about 2/3 of wing width, a wavelike median patch along midline and somewhat fused with upper grayish-brown area on costal margin, and a postmedian spot separated from median patch; rusty scales as thin line extending from base of wing along midline to about 1/4 of wing length, and merging gradually with forewing background color between basal spot and postbasal line. Hindwing gray; fringe grayish beige. Subcostal brush absent. Abdomen dorsally pale beige; ventrally off-white, with tuft of long scales on each side of genitalia off-white. Sclerotized hook absent on segment VII. Genital flaps rounded, elongated and thin; arising on both sides at apex of sclerotized sternum VIII.

Male genitalia (n=1) (Fig. 19). Right uncuslike process straight and blunt tipped, about 2 X length of left process. Tegumen wide, heavily sclerotized along margins, dorsoventrally flattened. Valvae symmetrical, spoon-shaped with short arms broader distally, slightly upcurved, adorned with setae disposed comblike along dorsal margin, with two thin sclerotized spurlike setae of same length on each valva. Phallus heavily sclerotized, bulbous near middle, second half slightly angled downward; vesica without spines or cornuti. Anellus with two symmetrical lobes, not enlarged, both adorned with small setae, with very long setae at apex.

Female. Unknown

Larval case (n=11). Burrito-shaped, 4.5–8.7 mm in length, similar to that of *H. nihoa*.

Etymology. The name of *H. papahanau* is short for Papahānaumokuākea, which is the goddess who gave birth to the NWHI in the Hawaiian mythology and the name of the recently proclaimed Marine National Monument that encompasses all the NWHI.

Biology. Adults were reared from case-making larvae. Larvae were collected on the ground during the day on the island of Nihoa in July.

Distribution. Known only from the NWHI of Nihoa where it is presumed to be endemic.

Conclusions

The eight new species here described suggest that the NWHI support a surprising diversity of *Hypsmocoma*, especially considering the harsh dry conditions on these small, isolated islands. Systematic work, building on the taxonomic framework of this research, may begin to address questions regarding the age and origin of NWHI *Hypsmocoma*. The diversity of case types and species on the NWHI, including at least two additional undescribed species, one purse case type from Nihoa and one burrito case type from Necker which we were unable to rear, suggest that *Hypsmocoma* has multiple lineages (not just species) that have either persisted on or dispersed to NWHI. This is of particular relevance to the theory of island biogeography (MacArthur & Wilson 1967) which predicts that small, isolated islands will have relatively high rates of extinction and very low rates of colonization. In this context, these new species descriptions represent a dramatic increase in our understanding of *Hypsmocoma* diversity in the NWHI, not only in the number of species, but perhaps more significantly in the diversity of lineages as reflected in the number of different case types found on different islands. Each of the islands of Laysan, Necker, and Nihoa harbor one purse case species and one cone case species. In contrast, the burrito case type is apparently absent, or extinct, from Laysan while one species is found on Necker and at least three different species of burrito case type are found on Nihoa, the youngest of the three islands. Also cone, burrito, and purse case-bearing species are all found in the main Hawaiian Islands (e.g. Rubinoff 2008, Schmitz & Rubinoff 2008) suggesting that NWHI species may represent more basal lineages, or a remarkable series of more recent colonizations from the main islands up to these tiny receding islets. Under either scenario, the biogeography of NWHI *Hypsmocoma* has broad implications for our understanding of island extinction/colonization dynamics.

Acknowledgments

We thank Betsy Gagné and the Division of Forestry and Wildlife, Department of Land and Natural Resources for permits. We are grateful to Cindy Rehkemper and Mike Richardson (U.S. Fish and Wildlife Service), Cynthia King, Jesse Eiben, and Steve Montgomery, for assistance with collecting. We also thank Clinton Pong, Talon Tengan, Dan Nitta, and Jane Winhall-Rice for assistance with rearing larvae, Samuel ‘Ohukani‘ōhi‘a Gon III (The Nature Conservancy, USA) for help with Hawaiian names, Alex Gumovsky (Schmalhausen Institute of Zoology, Ukraine) for parasitoid identification, and Bernard Landry (MHNG), Klaus Sattler (BMNH), and an anonymous reviewer for useful suggestions that improved the manuscript. This research was conducted under permit from the Papahānaumokuākea Marine National Monument and supported in part by grants from the National Geographic Society's Committee for Research and Exploration, and by the State of Hawaii's U.S. Fish and Wildlife Service State Wildlife Grant (T-3-P). Additional funding was provided by the National Science Foundation (USA) project # DEB-0918341. P. Schmitz was supported by a Swiss National Science Foundation postdoctoral grant (PBGEA/119-332).

References

- Bonacum, J., O'Grady, P.M., Kambyzellis, M. & DeSalle, R. (2005) Phylogeny and age of diversification of the *planitibia* species group of the Hawaiian *Drosophila*. *Molecular Phylogenetics and Evolution*, 37, 73–82.
- Fullaway, D.T. (1914) A list of Laysan Island insects. *Proceedings of the Hawaiian Entomological Society*, 3, 20–22.
- Jordan, S., Simon, C. & Polhemus, D. (2003) Molecular systematics and adaptive radiation of Hawaii's endemic damselfly genus *Megalagrion* (Odonata: Coenagrionidae). *Systematic Biology*, 52, 89–109.
- MacArthur, R.H. & Wilson, E.O. (1967) *The Theory of Island Biogeography*. Princeton University Press, Princeton, NJ, USA.
- Price, J.P. & Clague, D.A. (2002) How old is the Hawaiian biota? Geology and phylogeny suggest recent divergence. *Proceedings of the Royal Society of London B*, 269, 2429–2435.
- Rubinoﬀ, D. (2008) Phylogeography and ecology of an endemic radiation of Hawaiian aquatic case-bearing moths (*Hyposmocoma*: Cosmopterigidae). *Philosophical Transactions of the Royal Society of London B*, 363, 3459–3465.
- Schmitz, P. & Rubinoﬀ, D. (2008) Three new species of *Hyposmocoma* (Lepidoptera, Cosmopterigidae) from the Hawaiian Islands, based on morphological and molecular evidence. *Zootaxa*, 1821, 49–58.
- Swezey, O.H. (1926) Lepidoptera. In: *Insects of Hawaii, Johnston Island and Wake Island*. *Bulletin of the Bernice P. Bishop Museum*, 31, 73–79.
- Walsingham, L. (1907) Microlepidoptera. In: Sharp, D. (ed.), *Fauna Hawaiiensis*, Vol. 1. Cambridge University Press, Cambridge, United Kingdom, pp. 469–759.
- Zimmerman, E.C. (1978) Microlepidoptera. In: *Insects of Hawaii*, Vol. 9. The University Press of Hawaii, Honolulu, USA.